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A SEARCH FOR NEW OBSERVATORY SITES IN AUSTRALIA*

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The southern hemisphere is woefully lacking in observatories and major telescopic equipment. We find south of the equator two 74-inch reflectors, and none larger, and the total number of research observatories can be counted on the fingers of two hands. The northern hemisphere observatories have about a dozen instruments with apertures greater than 70 inches either in operation or under construction, and this number will most likely rise considerably within the next decade. There is a listing of the world's observatories in the *Astronomical Ephemeris* for 1960 which shows 291 observatories in northern latitudes as against 26 in southern latitudes. And yet it is hardly necessary to remind readers that only in the southern hemisphere can some of the most critical sections of the heavens be observed. The Magellanic Clouds lie 70° to the south of the celestial equator, Carina and the Southern Coalsack sections of the Milky Way are near declination 60° south, and the centre of our Milky Way System passes overhead at latitude 30° S. We obviously need more observatories in the southern hemisphere and more telescopes—and along with these more astronomers.

Where should the future southern hemisphere telescopes be located? The southern halves of the three great continents have many potentially useful sites and astronomers have bestirred themselves in recent years to find the best of these. The most extensive search for the best site has been

*Mount Stromlo Observatory Reprint No. 33.

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carried out in South Africa in connection with the project for a Joint European Southern Observatory. A comprehensive report has been published by J. Dommanget (1958) on the techniques employed by the Dutch, Belgian, Swedish, German and French astronomers and on the results obtained to date. Site testing is in progress in South America where—among others—Isadore Epstein has been using the techniques developed and tested by him and his associates in the Yale-Columbia survey of Australia from 1957 to 1959. Plans are under way for fairly extensive tests in New Zealand, and in Australia the work is now also well in hand. I shall, in this present article, confine myself entirely to the search for suitable sites now in progress in Australia.

One might ask "Why not locate a future large telescope in Australia at or near one of the existing observatories?" The answer to this question is simply—and do not blame the Australians, the same thing has happened the world over—that the existing observatories are not in the best places for observation at night. Take, for example, the century-old observatory in Sydney. It is right in the heart of the city and the big ships from Europe and America entering Sydney Harbour sail past within a stone's throw of Sydney Observatory. In Western Australia, Perth Observatory occupies a beautiful site in a park in the heart of metropolitan Perth and the city lights are a problem. Excessive rainfall, cloudiness and wind render the coastal regions unsuitable for further major telescopic development in any case. Mount Stromlo Observatory is located well inland at an altitude of 2,600 feet, but because of the proximity of a cloud-gathering mountain range, which rises to 5,000 feet, it does not have the required freedom from night cloudiness. At Mount Stromlo there were, during 1959, 196 nights on which the 74-inch reflector was operable, with a total number of observing hours equal to 1613, of which number, however, only two thirds were suitable for photoelectric work. There should be on the Australian continent many places with 50 per cent. or more of all nights usable for photoelectric work, and we must find where these places are before we decide on any future new observatory developments in Australia.

At the moment, Australian astronomers are concerned with two distinct search programmes for new observatory sites. The first project is to find a suitable site for a Field Station for Mount Stromlo Observatory, preferably located within one day's drive of Mount Stromlo. This search is at present limited to New South Wales, with one additional site under consideration in the state of Victoria. The other project is an attempt to locate a first-class site anywhere on the Australian continent, which might be used for future major observatory developments, be it

either a purely Australian observatory, a British Commonwealth observatory or some major international observatory project. Since some of the potentially most favoured sites are in the states of Western Australia and South Australia, this second search programme must of necessity be of a far more sweeping nature than the first. Work on both projects is already well under way.

A few comments may be in order with regard to the precise nature of the future Mount Stromlo Observatory Field Station. We are not considering the abandonment of the present site, or the transfer of all major equipment to a new site, but we do wish to establish a conveniently-located Field Station with more steady and clear night skies than at Mount Stromlo and with at least equally good average seeing. Here we would plan to erect all new equipment that comes our way. Added importance is given to this project by the announcement last year of the establishment of a Department of Astronomy at Sydney University, the

FIG. 1—Localities in Australia for which 9 p.m. tests of night cloudiness are in progress.

first such Department at any of Australia's State Universities. It is the intention of Sydney University to build a Field Station somewhere in New South Wales, preferably adjacent to the site for the Mount Stromlo Observatory Field Station.

Historically, the first comprehensive published report on observing conditions for modern astronomical and astrophysical work in Australia was prepared by the Government Astronomer of New South Wales, Harley Wood, who, in his Presidential Address to the Royal Society of New South Wales (1951), gave what is still the best general review of the situation. Early in 1959, the Yale and Columbia Observatories issued a duplicated report on a Site Testing Survey carried out between 1957 and 1959 by Isadore Epstein, which survey covered the entire Australian continent. The Mount Stromlo survey was begun in earnest in the middle

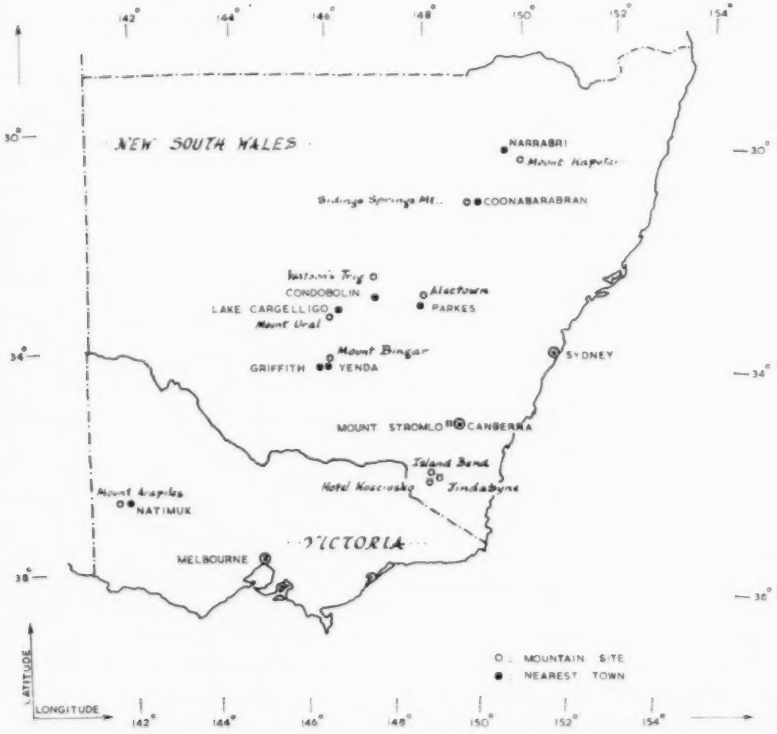

FIG. 2—Stations in New South Wales and Victoria.

of 1958 and it has now progressed to the stage where the search for sites for a Mount Stromlo Field Station has narrowed down to four selected localities. The sites at present favoured for the Field Station are Mount Bingar near Griffith and Yenda, New South Wales (figures 1 and 2), Watson's Trig, on top of Boona Mountain near Condobolin, New South Wales (no. 6), and Mount Arapiles near Natimuk, Victoria (no. 8). The Control Station for the New South Wales and Victoria surveys is now established on top of Mount Bingar.

Where in Australia may one expect to find good observatory sites? We must obviously have at least 50 per cent. of all nights clear and suitable for astronomical work, but there are additional considerations which assist us in limiting right from the start the area over which the search must be extended.

The first of these considerations is that we should locate our observatory as far south as is practicable. We want to be able to observe interesting regions with declinations between 60° S. and 75° S. for as many hours as possible on clear nights; this consideration alone suggests that a latitude of 35° S. has many advantages over 30° S., and that 25° S. is already too far north. Hence we need to search only to the south of latitude 25° S.

The second consideration is that—with other things being equal—we prefer to have the highest frequency of clear skies at night in the Australian spring and summer (September to March), simply because these are the seasons when the Magellanic Clouds are most favourably placed for observation. So much important work remains to be done on the two Magellanic Clouds that special attention must be paid to them in any project of site selection. Most of the existing southern hemisphere observatories are not well placed in this respect. Mount Stromlo Observatory has a fair number of partially clear nights during the Magellanic Cloud observing season, but nights of photometric quality are rare during the summer months. It is therefore important that we should try to have good night skies between September and March for the new site.

A third consideration is that of height above the level of the surrounding country. Unfortunately Australia possesses few mountains that rise to 5,000 feet, and the few that do exist are either not free from clouds or are too inaccessible and isolated. Our minimum requirement for a site is that it must be not less than 800 feet above the level of the surrounding plain, with our first preference going to isolated hilltops and mountain ranges. This condition gives one a fair chance of remaining above the nocturnal inversion layer and the turbulent features—which produce poor seeing—associated with this layer.

A fourth factor, and a major one for Australia, is that the site should be in an area relatively free from dust and bushfire smoke—a condition not easy to satisfy in arid Australia, renowned for its dust storms.

With these desiderata in mind, we may now examine briefly the weather patterns of Australia as they affect our search.

To the south of the Australian continent, there is a vast expanse of stormy and turbulent ocean, and many of the major low pressure patterns which affect the Australian continent pass with their centres rather close to the southern shorelines. We may therefore expect stable and clear night skies only well to the north of the line of the three great coastal cities, Melbourne, Adelaide and Perth. In the winter-time, the tracks of the centres of low pressure generally run to the north of their mean paths, in the summer-time they pass farthest south. The tropical northern half of Australia is affected by the monsoonal rains, which reach farthest south in the Australian late summer and early autumn. Northern Queensland is the one part of the arid Australian continent known for its abundant and torrential rainfall!

Over the Australian continent we find therefore a belt of dry and clear skies, which is widest at the western end and which narrows towards the east coast. Its southern border runs about one hundred miles north of Perth to 200 miles north of Adelaide and then follows pretty well the 35th parallel. In the Australian winter this boundary moves slightly northward, in summer slightly southward. We may therefore limit our survey to the belt between 25° S. and 35° S. latitude.

It is important that observations of night cloudiness be made for the sites which appear to warrant careful further study. In the Mount Stromlo survey the list of preferred sites contains twenty entries. Each potential site was visited by two or more staff members and, as a first step, arrangements were made with a resident observer to study the sky each night at about 9 p.m. and record certain ratings of astronomical significance. A Grade *A* is given when there is no cloud or haze higher than 10° above the horizon, and Grades *B* and *C* are given for gradually deteriorating skies. Next, an observation is made for vertical visibility, with Grade *A* reserved for nights on which the stars appear sharp and brilliant against dark skies, and Grades *B* and *C* indicating hazy or very hazy nights. We ask the observers to note the presence of bushfire smoke or dust. Then an observation is made of the scintillation, with Grade *A* indicating that scintillation is absent or very slight, and *B* and *C* showing increasing scintillation. Wind force and direction and cloud quarter are observed and we ask our observers to record in addition the general nature of the weather the morning after. We thus obtain a fair indication

whether or not, at 9 p.m., the night was a good one for astronomical observations and we have some suggestion, from the morning observations, as to the probable quality of the night from 9 p.m. until dawn.

The twenty stations that are now under surveillance in our Australia-wide survey are listed in Table I and marked on figure 1. Table II shows the results obtained to date. The present site of Mount Bingar Control Station is shown as no. 2 on the map and the favoured stations for comparative tests of seeing against the seeing at the Mount Bingar Station are nos. 3, 6 and 8 on the map. For each of the stations in New South Wales (see figure 2), we intend to complete either a two-year cycle of 9 p.m. observations of night cloudiness (for the more promising ones), or a one-year cycle for those showing the least promise. A full two-year cycle of 9 p.m. observations will be completed for each station in South Australia and Western Australia.

Once the minimum conditions for a good site are satisfied, the most important considerations in favour of one site or another are those relevant to the quality of astronomical seeing and its variation with time. To judge sky stability at a site, one should also make observations of atmospheric extinction, preferably by photoelectric techniques. Our present plan is to make seeing and extinction observations at selected sites that show real promise, the first of these being Mount Bingar Control Station, near Griffith and Yenda, New South Wales.

TABLE I

TEST SITES OF MOUNT STROMLO OBSERVATORY

Site	Long. E.	Lat. S.	Altitude
	° ′	° ′	ft.
1. Mount Stromlo	149 01	35 19	2567
2. Mount Bingar	146 14	34 07	1494
3. Watson's Trig	147 10	32 38	1520
4. Lake Cargelligo	146 23	33 18	1810
5. Alectown	148 15	32 56	2391
6. Coonabarabran	149 17	31 16	3500
7. Narrabri	149 50	30 19	4900
8. Natimuk	141 57	36 45	1176
9. Island Bend	148 30	36 18	5922
10. Hotel Kosciusko	148 31	36 21	5835
11. Jindabyne	148 37	36 24	4000–7316
12. Giles	128 15	25	
13. Ernabella	132 07	26 22	4723
14. Alice Springs	133 53	23 42	
15. Angepena Homestead	138 51	30 34	3060
16. Mount Singleton	117 18	29 27	2290
17. Mount Yagahong	118 39	26 53	2280
18. Kalgoorlie	121 28	30 45	
19. Coolgardie	121 10	30 57	1822
20. Mount Grey	118 05	31 02	1735

TABLE II

PERCENTAGE DISTRIBUTION OF NIGHTS CLOUDLESS AT 9 P.M., FOR TEST SITES OF MOUNT STROMLO OBSERVATORY

Site	1958: Jun %	Jul %	Aug %	Sep %	Oct %	1959: Nov %	Dec %	Jan %	Feb %	Mar %	Apr %	May %	Jun %	Jul %	Aug %	Sep %	Oct %	Nov %	Dec %	1960: Jan %	Feb %	Sep. 59–Feb. 60 Average % of Clear Nights
Mount Stromlo	23	19	28	38	23	19	26	32	26	29	42	73	36	45	39	33	19	23	35	42	28	30
Mount Bingar	66	50	43	60	33	50	76	57	44	36	70	90	37	32	48	57	39	70	45	45	55	52
Watson's Trig	43	53	41	50	47	40	60	43	43	50	70	83	56	32	71	60	45	57	77	42	45	54
Lake Cargelligo	33	37	31	43	37	27	66	43	47	40	67	83	46	23	45	53	23	37	45	29	45	39
Alectown			20	33	33	27	60	47	40	34	66	83	47	61	74	67	39	73	61	45	48	56
Coonabarabran														55	87	57	52	53	71	42	55	55
Narrabri													50	45	71	40	61	53	58	39	41	49
Natimuk						44	77	80	60	57	62	83	53	39	42	40	48	53	48	58	62	52
Island Bend											35	54	30	26	26	40	16	20	19	27	41	27
Hotel Kosciusko													20	29	29	30	10	40	13	27	41	27
Jindabyne											43	57	40	39	42	30	16	20	35	35	41	30
Giles																50	71	63	48	45	38	53
Ernabella														50	61	43	45	40	38	42	48	43
Alice Springs																	74	57	61	35	69	59
Angepena Homestead																					52	52
Mount Singleton																72	65	78	84	77	41	70
Mount Yagahong																43	81	57	55	45	21	50
Kalgoorlie																50	74	77	71	68	52	65
Coolgardie																53	77	80	84	65	55	69
Mount Grey																67	61	83	84	77	52	71

On Mount Bingar, we have a 26-inch reflector at present in operation (figures 3 and 4). The primary mirror of the reflector is a thick-ribbed, honeycomb disk of pyrex, which was made available to us by the Fund for Astrophysical Research of the United States. A 10-inch secondary was ground and polished in the Observatory's Optical Shop and the telescope tube and mirrors were placed on the redesigned equatorial mounting of the 20-inch Catts reflector. The erection of the telescope at Mount Bingar was completed on December 22, 1959, and observing began in earnest on the night of December 25. During the three months that have so far elapsed, the telescope has been in operation on photoelectric programmes. Between December 25 and April 3, the author has been at Mount Bingar on 31 nights; 17 nights were mostly excellent for photoelectric work, five were half clear, one one-quarter clear, two were hazy and would have been useful only for work with a slit-spectrograph and exposure meter, and six were cloudy nights. With few exceptions, the extinction results on the good nights have been quite satisfactory. Seeing has been good to excellent on most nights and on only a few nights have we observed bad seeing of the type that plagues astronomers with large telescopes at many established observatory sites. Dust has not been much of a problem at Mount Bingar, which is located 1,000 feet above the surrounding plain, but we have been a little bothered by gusty

FIG. 3—The building of the 26-in. reflector on top of Mount Bingar.

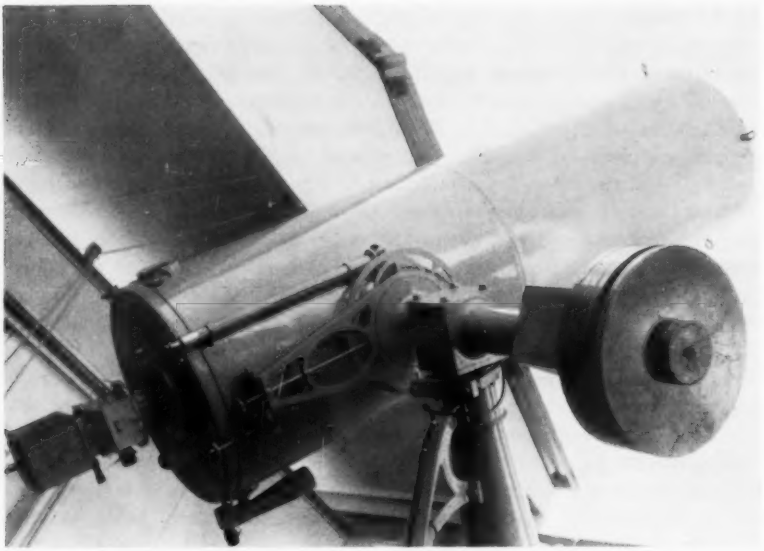

FIG. 4—The 26-in. reflector with the photoelectric photometer attached.

winds, which are making it necessary to replace our sliding roof by a simple revolving dome. Much useful work has already been accomplished on colour and magnitude studies of stars in the Large Magellanic Cloud and in the Carina and Centaurus sections of the Milky Way; the site looks indeed like a promising one. The results for Mount Bingar, while very encouraging, are of course not conclusive and we intend to continue observations regularly at the site from now on, to learn all that is possible about its good points and defects.

The comparative tests of astronomical seeing at the other three sites which are receiving special consideration in New South Wales and Victoria will probably be carried out with a specially designed polar telescope. Theodore Dunham, Jr.—who with Kurt Gottlieb is responsible for the design of this instrument—has prepared the following brief description of the polar telescope:

"The attached sketch (figure 5) shows the general arrangement. A 12-inch flat mirror, mounted in a fork on the upper end of a polar axis, directs the light from a star upward along the axis to an 8-inch concave spherical mirror with a focal length of 96 inches (f/12). This mirror requires no parabolizing, and is of high quality. It returns the converging beam, on axis, to a reflecting prism just above the flat mirror. The focus

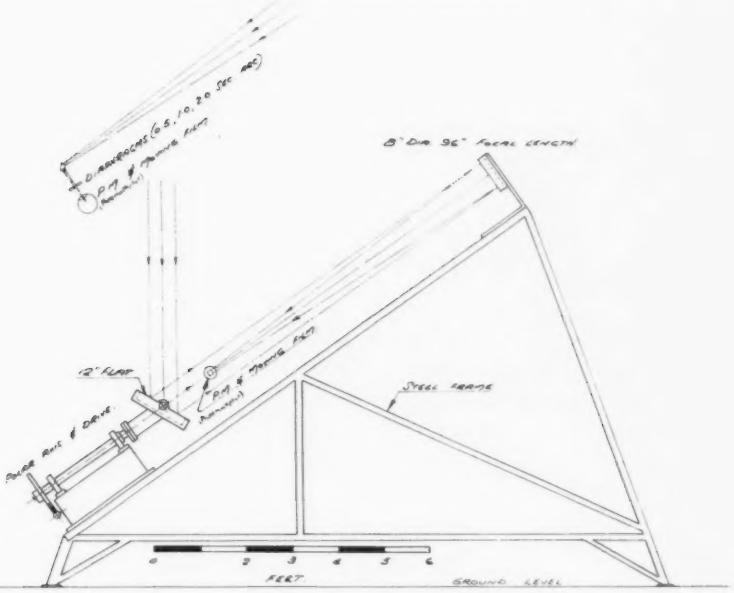

FIG. 5—Plan of the polar telescope.

is to one side, where it is easily accessible, and where measuring and recording equipment can easily be mounted. A polar axis, with well-separated bearings and electric or centrifugal drive, with differential gears for guiding, is being used. Accurate adjustment in declination is also being provided. The two optical units will be mounted on a rigid, triangular welded frame, which rests on the ground.

"The optical units, polar axis and drive will be removable. Four steel frames will probably be made and set up, initially at Mount Bingar, on Boona Mountain and near Coonabarabran in New South Wales and near Natimuk in Victoria. The optical units can easily be attached to the frames at each station."

The first polar telescope is now under construction in the Mount Stromlo Workshops. The present plan is to compare several methods for examining and measuring stellar images, notably the following: 1. Visual inspection of the diffraction ring structure and motion with respect to a reference wire; 2. Visual inspection of double stars and possibly planets; 3. Photographic recording of the image; 4. Photoelectric measurement of image diameter. Extinction observations may also be made with the

same equipment. We propose at present to have a roving observer who will travel from one site to the next, spending approximately ten days at each site and returning every six to eight weeks to Mount Bingar to check his results against those obtained with the 26-inch reflector. Within about a year we hope to be able to decide firmly and finally on a site for the Mount Stromlo Field Station.

In all likelihood the testing of the sites in South Australia and Western Australia will follow the same pattern. With our limited resources it will probably be necessary for us to complete the New South Wales and Victoria surveys before becoming too deeply involved in the surveys for South Australia and Western Australia. We intend to extend our work to the very promising sites in the latter States as soon as funds and personnel permit us to do so. We hope to bring our survey to a conclusion at the earliest possible date, but unfortunately site testing cannot be hurried. In order to obtain anything like a fair picture of conditions at any one spot, it is necessary to observe there for a minimum of one year, preferably longer, since Australia is renowned for its variable sky conditions from one year to the next.

We expect that the studies by the Mount Stromlo group, combined with the earlier work already referred to above, will give us, within a reasonable time, a clear picture of conditions for astronomical observations at the most promising sites in Australia. Statistics of night cloudiness at the favoured sites in New South Wales and Victoria show that conditions appear to be quite good, and we are already sure that a really satisfactory site for a Field Station for Mount Stromlo Observatory will be found. However, we must admit that, on the basis of night cloudiness conditions alone, Western Australia or South Australia seem so far to be more suitable as potential sites for a new and major observatory development which is not part of Mount Stromlo Observatory. Eventually the seeing and extinction tests will probably be the deciding factor, for they best determine the effectiveness of telescopic work carried out at a site where at least 50 per cent. of the nights are clear.

The fruits of the present work will, of course, be enjoyed first of all by the Australian astronomers themselves, but, especially in connection with our more extended survey, we feel at all times that we are doing a job for the astronomical world at large and that we are truly opening up the Australian continent for research work by astronomers of all nations.

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OFFICIAL OPENING OF THE DOMINION RADIO ASTROPHYSICAL OBSERVATORY, WHITE LAKE, PENTICTON, B.C., JUNE 20, 1960

By G. J. Odgers

Dominion Astrophysical Observatory, Victoria, B.C.

On the afternoon of Monday, June 20th, in fine weather, but with a stiff breeze troubling the speakers a little, the Hon. Paul Comtois, Minister, Department of Mines and Technical Surveys, formally opened the Department's new Observatory, to be known as the Dominion Radio Astrophysical Observatory, before an audience of over 150 scientists and other guests from both Canada and abroad. The Minister emphasized the importance with which the Government regards fundamental scientific research and contrasted the unprejudiced and international manner of science with the unsatisfactory nature of mankind's achievements in the more general fields of international relations and mutual tolerance. The Dominion Astronomer, C. S. Beals, traced the history of astronomical research in Canada, and showed how the need for a large radio telescope developed from the general galactic researches already pursued and showed the continuity of this new effort with instrumental developments in the past. The President of the National Research Council, E. W. R. Steacie, speaking as a chemist, gently rebuked his astronomical colleagues for their ill-concealed pride in the very large and costly apparatus they require, with the advent of space explorations becoming costlier than ever, and in their ability to choose beautiful sites for their studies. He referred to the fact that science and politics are now inextricably connected, giving rise to many very difficult decisions but also leading to a great increase in governmental scientific effort. The officer-in-charge of the new Observatory, J. L. Locke, described the search for a suitable site and enlarged on the eminently satisfactory qualities of the valley in which we found ourselves, both aesthetically and for the purposes of radio astronomy. The problems of the structure and motion of gas-clouds in the galaxy, and the existence of large-scale magnetic fields would be vigorously pursued with the new telescope, one of the finest such instruments in operation, he stated.

Not to be forgotten was the comment of his Worship, Mayor Oliver of Penticton, "what a tourist attraction"!

The 84-foot telescope was seen in action immediately after the opening addresses, being set in motion after M. Comtois pressed the appropriate button. As it slowly traversed the strong radio source Cassiopeia A the

FIG. 1—Dominion Radio Astrophysical Observatory, White Lake, Penticton, B.C., showing the 84-foot radio telescope and the office building on opening day, June 20, 1960. (Photo by *Penticton Herald*.)

signal was broadcast over the public address system to be clearly heard by everyone.

A tour of the office building and grounds followed and the staff-members explained the operation of the control panel of the telescope and the intricacies of the receivers being used with it. In the evening a

very enjoyable reception was given at the home of Dr. and Mrs. Locke on the shores of Skaha Lake; a feature of this evening was a short concert of French-Canadian songs conducted by M. Comtois, and ably assisted by Maarten Schmidt—from Leiden by way of Pasadena.

Under the joint sponsorship of the National Committees for Canada of the International Astronomical Union and the International Union of Radio Science a symposium on the objectives of radio astronomy was held on Tuesday and Wednesday, June 21 and 22. In the first paper P. E. Argyle of the D.R.A.O. staff discussed his design of a proposed 100-channel receiver at 21-cm. wave-length suitable for use with the radio-telescope and later C. H. Costain gave an account of work at Cambridge on low frequency antennas and described a large (about a mile across) "T" antenna which is to be built at White Lake. In the afternoon David Hogg summarized our knowledge of the radiation from thermal sources in the galaxy, while the paper by Donald A. MacRae (read in his absence) discussed other galactic radiation. G. A. Harrower followed with a talk on the distant radio sources and their importance to cosmological theories.

After the dinner on Tuesday evening at the Prince Charles Hotel, Penticton, Dr. Beals read various congratulatory messages to the new Observatory including a long and eloquent address in Latin from Cambridge. The principal speaker, Maarten Schmidt of the California Institute of Technology, then gave a thorough account of our present knowledge of galactic structure obtained from both optical and radio observations (this talk will be published in a forthcoming issue of the JOURNAL).

On Wednesday morning his long continued and well-known work on the sun was discussed by A. E. Covington, and P. M. Millman gave an interesting account of what might be called "radar-astronomy", namely the direct radio contact of meteors and planets. In the open session in the afternoon this subject was much amplified and proposals were made for the use of the Prince Albert (Sask.) 84-foot radar. With the prospect of more powerful transmitters in the near future radar contacts with the nearer planets becomes a useful means of interplanetary investigations. D. S. Heeschen and Schmidt gave accounts of current work at Green Bank, West Virginia, and at Owens Valley, California, and Dr. Schmidt re-emphasized the need for more precise galactic surveys than now exist and which could be undertaken at the D.R.A.O.

Various events of a semi-sporting nature took place during lunch hours during these meetings. Several well-known astronomers showed their ability to climb ladders to great heights, and many of the delegates had

a ride to the telescope focus some 50 feet above ground level in the hoist "Girette".

Dr. Locke and the staff are to be congratulated on their fine achievement in bringing this powerful research instrument into operation so quickly.

FIG. 2—*Front row*: Peter M. Millman, N.R.C., Ottawa; A. E. Covington, N.R.C., Ottawa; R. M. Petrie, D.A.O., Victoria; Mrs. Petrie; J. L. Locke, D.R.A.O., Penticton; M. Schmidt, Cal. Tech., Pasadena; Helen S. Hogg, D.D.O., Toronto; C. S. Beals, D.O., Ottawa; G. A. Harrower, Queen's U., Kingston; Mrs. Noyes. *Second row*: Miriam Burland, D.O., Ottawa; C. H. Costain, D.R.A.O., Penticton; B. W. Currie, U. of Sask., Saskatoon; P. E. Argyle, D.R.A.O., Penticton; Ruth J. Northcott, D.D.O., Toronto; H. P. Gush, U. of T., Toronto; W. Wehlau, U. of Western Ont., London; J. B. Oke, Mt. W. and Palomar Obs., Pasadena; David E. Hogg, D.D.O., Toronto; J. C. Noyes, Boeing Sc. Res. Labs., Seattle; Jean Stilwell; Walter H. Stilwell, U. of Alberta, Calgary. *Third row*: M. Pruesse, D.R.A.O., Penticton; A. R. Hamilton, D.R.A.O., Penticton; D. S. Heeschen, N.R.A.O., Green Bank; J. H. Meek, D.R.B., Ottawa; D. R. Hansen, Prince Albert Radio Lab., Prince Albert; D. W. R. McKinley, N.R.C., Ottawa; D. C. Rose, N.R.C., Ottawa; R. Grenzeback, D. S. Kennedy and Co., Cohasset; J. W. Warren, U.B.C. and D.R.A.O., Penticton; R. M. Chisholm, Queen's U., Kingston. *Back row*: T. R. Hartz, D.R.B., Ottawa; J. L. Yen, U. of T., Toronto; M. M. Thomson, D.O., Ottawa; G. J. Odgers, D.A.O., Victoria; W. J. Medd, N.R.C., Ottawa; J. A. Galt, D.R.A.O., Penticton; F. Park, N.R.C., Ottawa; N. Broten, N.R.C., Ottawa; Jack Grant, Meanook Meteor Obs., Athabaska; R. W. Tanner, D.O., Ottawa; K. O. Wright, D.A.O., Victoria. *Absent when picture was taken*: B. L. White, U.B.C., Vancouver; H. L. Welsh, U. of T., Toronto; J. M. Lansinger, Boeing Sc. Res. Labs., Seattle; H. Penfield, Ewen Knight Corp., East Natick; S. H. Neddermeyer, U. of Wash., Seattle. (Photo by Redivo.)

THE OBSERVATION OF A SOLAR EVENT IN WHITE LIGHT FROM RESOLUTE N.W.T. ON AUGUST 30, 1957

By L. R. McNarry

National Research Council, Ottawa, Ontario

While operating an Auroral Radar at Resolute (74.9°N., 94.9°W.) for the National Research Council during the I.G.Y. my interest in solar flares and associated terrestrial events was aroused by the observation that solar radio noise emissions were recorded by the radar receiving system at a frequency of 48 mc./s. An Esterline Angus recorder was connected to the receiver system to record solar noise storms and outbursts. Routine observations of the sun, using a small 6× binocular,

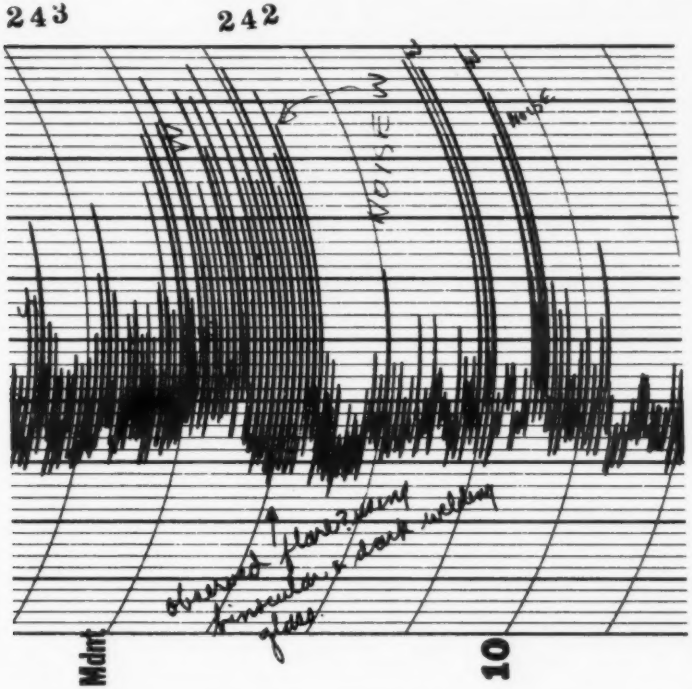

Fig. 1—Resolute Auroral radar noise record for period 22:00–24:00 hours U.T. August 30, 1957.

enabled plots of the major sun-spot groups to be made so that possible correlations of sun-spots and the noise records could be checked.

At 23:30 U.T. August 30, 1957, the chart record indicated that a noise storm had been in progress for about ten minutes. The sun was immediately observed with the binocular[1] and an area of intense brilliance was seen just "under" a large cluster of sun-spots located at approximately N10-E20 (McMath Plage Region 4124). The brilliance was such that the bright area appeared almost white when viewed through a piece of dark glass which allowed comfortable viewing of the normal sun. This indicates an intensity much greater than that of the normal photosphere. The bright area was about the size of the sun-spot cluster, irregular in shape, and was visible for 20 minutes. By 01:00 U.T. August 31, this area was indistinguishable from the photosphere and the radar noise level had subsided to a nearly normal value.

It is unlikely that this event was due to bright faculae since it was so far removed from the limb and the brightness was so intense. Faculae have since been observed with a 50× telescope, but none have remotely approached the brilliance of the Resolute observation. The significance of a visual observation of a solar flare was not realized at the time; however, it is thought that this observation may be of a unique character and should be put on record. It is indeed unfortunate that there are no recorded flare patrol observations for this period[2, 3].

REFERENCES

1. Resolute Auroral Radar Log Book entry for August 30, 1957.
2. Daily Maps of the Sun, July 1, 1957–December 31, 1958, Tokyo Astronomical Observatory.
3. *I.A.U. Quarterly Bulletin of Solar Activity* No. 119.

ELEMENTS OF ASTROMECHANICS

By Peter van de Kamp
Sproul Observatory, Swarthmore, Pennsylvania

VI. Analysis of Double Star Orbits. Stellar Masses and Unseen Companions

1. *True and apparent orbit*

The determination of the orbit of a celestial object involves its oriental tion in space. The earth's orbital motion complicates the observed orbita- motion of planets and comets. The latter complication is conspicuously absent from the *relative orbit* of the components of a binary star.

We shall limit ourselves to the astrometric approach to binaries, or the study of orbits as seen projected on the sky, i.e., perpendicular to the line of sight. We distinguish between *resolved* and *unresolved astrometric binaries* depending on whether the components are observed separated or blended. The relative position of the fainter *secondary* star (B) referred to the brighter *primary* (A) is yielded by visual observations in polar co-ordinates: distance (ρ) and position angle (θ); by photographic observations in the form of equatorial rectangular co-ordinates

$$\Delta\alpha \cos\delta = \Delta x \qquad \text{and} \qquad \Delta\delta = \Delta y. \tag{6.1}$$

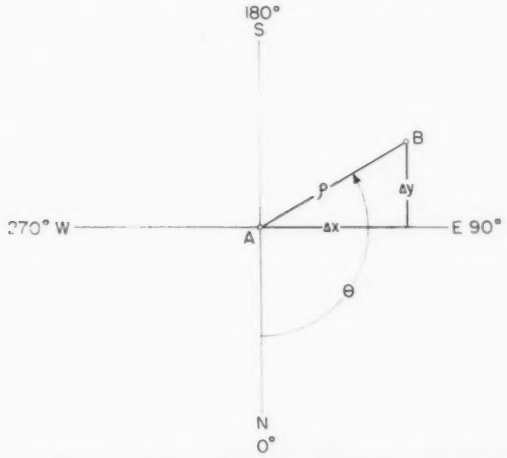

Fig. 6.1—Relative positions of double star components.

The following relations exist:

$$\begin{aligned} \Delta x &= \rho \sin \theta \\ \Delta y &= \rho \cos \theta \end{aligned} \tag{6.2}$$

$$\rho = \sqrt{(\Delta x)^2 + (\Delta y)^2} \tag{6.3}$$

$$\theta = \arctan \frac{\Delta x}{\Delta y}.$$

The relative orbit in its own plane is referred to as the *true orbit*, its orthogonal projection on the "plane of the sky" is the *apparent orbit*. The latter is obtained from observations and the first step is to draw the apparent orbit through the inherently imperfect observations in such a manner that it represents the projection of Keplerian motion. That is to say, the apparent ellipse has to obey the law of equal areas. Ideally, the observations should cover at least one full period of revolution. If not, an attempt is made to complete the apparent orbit on the basis of the observed part of the orbit.

The observations, or normal points thereof, in ρ and θ are plotted against the time t and are represented by interpolation curves, which are drawn and adjusted until the law of areas is satisfied, i.e., until values of $\rho_1\rho_2(\theta_2 - \theta_1)$ for equal intervals of times are equal to the so-called "areal constant".

2. *Dynamical and geometric elements*

It is logical and convenient to carry out the derivation of the true orbit from the apparent orbit in two steps. (See Chapter IV for definitions and explanations of various terms used in the present chapter.) First, we find the *dynamical elements*; second, the *scale* of the orbit (semi-axis major in seconds of arc) and the *orientation* elements. These are the three direction cosines: in practice, the inclination i; the angle ω, counted from the line of nodes to periastron in the direction of the orbital motion; and the position angle Ω, counted from the north point to the line of nodes. In the absence of observations of radial velocities no distinction can be made between the "ascending" and "descending" node and by convention Ω is taken as between 0° and 180°; the sign of i must be left undetermined.

The dynamical elements P, e and T may be derived as follows: the projected major axis is drawn through the bright star (projected focus F of the true ellipse) and the centre of the apparent ellipse—which corresponds to the centre of the true ellipse. This line indicates the position angle of periastron and apastron. Since the ratio focus-centre to focus-

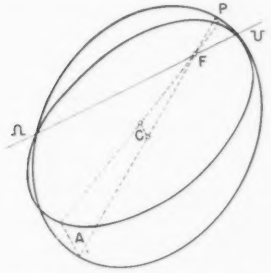

FIG. 6.2—Relation between periastron, apastron and centre in true and apparent orbits. The line of intersection or line of nodes Ω ℧ is taken to pass through the focus of the true orbit.

periastron is not changed by projection, the projected ratio of the bright star to the centre, and of periastron to the centre, determines the eccentricity e. The period P and the time T of periastron passage are found from a plot of the position angles against the time.

If the orbit has a high inclination, or virtually is seen on edge, the method outlined above will fail. In this case, use is made of the time-displacement curves in x or y or any other co-ordinate plotted against the time. In the true orbit periastron and apastron are half a period apart and equally far away on opposite sides of the centre. Moreover, the velocity vectors at periastron and apastron are in the ratio

$$\frac{V_P}{V_A} = -\frac{1+e}{1-e}. \tag{6.4}$$

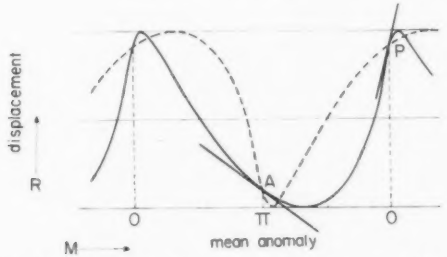

FIG. 6.3—Graphic determination of periastron (P), apastron (A), and of eccentricity from slopes of time-displacement curve at periastron and apastron respectively. The central line represents the centre of the orbit. Periastron and apastron are found as one pair of intersections of the time-displacement curve and its image inverted about the central line, shifted half a period along the time axis. The single intersection on the shorter, steeper branch, represents periastron; the corresponding intersection, half a period away, represents apastron.

These properties are not altered by orthogonal projection. Hence, in the displacement curves periastron and apastron are located as the pair of points on the displacement curve, $P/2$ apart in time and equidistant on opposite sides from the centre. The ratio of the slopes at periastron and apastron equals the ratio of the velocities (6.4) and thus e is found through the relation:

$$e = \frac{\left(\frac{dR}{dt}\right)_P + \left(\frac{dR}{dt}\right)_A}{\left(\frac{dR}{dt}\right)_P - \left(\frac{dR}{dt}\right)_A}. \tag{6.5}$$

The scale and orientation elements are found from the projection of the auxiliary or Kepler circle, called the *auxiliary ellipse*, obtained by expanding every point of the ellipse by the factor $1/\sqrt{1 - e^2}$ in a direction parallel to the projected diameter conjugate to the projected major axis. The semi-axis major a is then half of the longest diameter of the auxiliary ellipse; its direction Ω represents the line of nodes. The inclination i is found through its cosine which represents the ratio of the semi-axis minor of the auxiliary ellipse to the semi-axis major. The apparent ellipse may now be unprojected in the true ellipse and ω found.

3. *The "natural" geometric elements*

This elegant and instructive geometrical analysis of the scale and orientation elements is frequently replaced by analytical procedure. From

$$\begin{aligned} \Delta x &= \rho \sin \theta \\ \Delta y &= \rho \cos \theta \end{aligned} \tag{6.2}$$

and

$$\begin{aligned} ax &= r \cos v \\ ay &= r \sin v \end{aligned} \tag{4.8}$$

the following relations are found

$$\begin{aligned} \rho \cos (\theta - \Omega) &= r \cos (v + \omega) \\ \rho \sin (\theta - \Omega) &= r \sin (v + \omega) \cos i \end{aligned} \tag{6.6}$$

and finally the simple linear equations

$$\begin{aligned} \Delta x &= Bx + Gy \\ \Delta y &= Ax + Fy. \end{aligned} \tag{6.7}$$

Here x and y are the elliptical rectangular co-ordinates in the unit orbit, while

$$\begin{aligned} B &= a(\cos\omega \sin\Omega + \sin\omega \cos\Omega \cos i), \\ A &= a(\cos\omega \cos\Omega - \sin\omega \sin\Omega \cos i), \\ G &= a(-\sin\omega \sin\Omega + \cos\omega \cos\Omega \cos i), \\ F &= a(-\sin\omega \cos\Omega - \cos\omega \sin\Omega \cos i). \end{aligned} \tag{6.8}$$

The four geometrical elements B, A, G and F contain the scale a and the three orientation elements i, ω and Ω; they are named the "natural" elements or "Thiele-Innes" constants from which the "conventional" geometric elements may be derived from the following relations:

$$\begin{aligned} \tan(w + \Omega) &= \frac{B - F}{A + G} \\ \tan(w - \Omega) &= -\frac{B + F}{A - G} \\ \cos i &= \frac{m}{a^2}, \quad a^2 = j + k, \\ 2k &= A^2 + B^2 + F^2 + G^2, \quad m = AG - BF, \quad j^2 = k^2 - m^2. \end{aligned} \tag{6.9}$$

The projections on any co-ordinate are given by $(\gamma_1 ax + \gamma_2 ay)$ in the apparent orbit and $(\gamma_1 a \cos E + \gamma_2 a \sin E)$ in the auxiliary ellipse. Here γ_1 and γ_2 are the direction cosines of the projected co-ordinates on the directions x and y in the true orbit. Note that $\gamma_1 a$ is the projected co-ordinate of periastron ($E = 0$), $\gamma_2 a$ the projected co-ordinate of the point $E = 90°$ on the auxiliary circle; both co-ordinates refer to the centre of the orbit. Hence, in the equatorial co-ordinate system, the elements B, A and G, F represent the projections of periastron and of the point $E = 90°$ of the auxiliary circle. Note that these quantities are proportional to the scale a, and refer to the centre of the orbit.

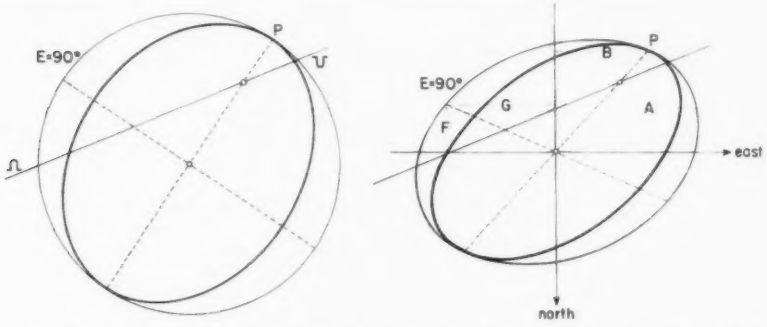

FIG. 6.4—(a) True orbit and auxiliary Kepler circle. (b) Apparent orbit and auxiliary Kepler ellipse in equatorial rectangular co-ordinate system.

4. *Masses and mass-ratio*

If, in addition to the angular measure a'' of the semi-axis major and the period P, the parallax p'' is known the linear value of a is found to be a''/p''. The combined mass of the two stellar components is then obtained through the harmonic relation

$$\mathfrak{M}_A + \mathfrak{M}_B = \frac{a^3}{P^2} \tag{2.32}$$

where the units for the mass, space and time dimensions are the sun's mass, the astronomical unit of distance and the sidereal year respectively.

The separate masses may be obtained by locating the centre of mass through its non-accelerated motion on a background of faint stars. The procedure commonly followed is the technique and methods of long focus photographic astrometry and is illustrated by the following formulae

$$\begin{aligned} X &= c_x + \mu_x t + \pi P_\alpha + \alpha Q_\alpha \\ Y &= c_y + \mu_y t + \pi P_\delta + \alpha Q_\delta. \end{aligned} \tag{6.10}$$

X and Y represent the measured positions; on the right hand side of the equation the first two terms represent the motion of the barycentre, the third term the displacement due to the annual parallax π, the last term the orbital displacement. P and Q are the parallax and orbital factors respectively.

Assuming the relative orbit to be known, the orbital factors Q_α, Q_δ may be calculated as follows

$$\begin{aligned} Q_\alpha &= (b)x + (g)y \\ Q_\delta &= (a)x + (f)y \end{aligned} \tag{6.11}$$

where

$$\begin{aligned} (b) &= -\cos\omega\sin\Omega - \sin\omega\cos\Omega\cos i, \\ (a) &= -\cos\omega\cos\Omega + \sin\omega\sin\Omega\cos i, \\ (g) &= +\sin\omega\sin\Omega - \cos\omega\cos\Omega\cos i, \\ (f) &= +\sin\omega\cos\Omega + \cos\omega\sin\Omega\cos i. \end{aligned} \tag{6.12}$$

These orientation factors are related to the Thiele-Innes constants as follows

$$\begin{aligned} B &= -(b)a, \\ A &= -(a)a, \\ G &= -(g)a, \\ F &= -(f)a. \end{aligned} \tag{6.13}$$

If the images of the components are separated, α represents the semi-axis major of the orbit of the bright component A relative to the centre of mass, i.e.

$$\alpha = \mathrm{B}a \tag{6.14}$$

where

$$\mathrm{B} = \frac{\mathfrak{M}_B}{\mathfrak{M}_A + \mathfrak{M}_B} \tag{6.15}$$

is the fractional mass of the faint component.

If the components' images are blended, the measurements refer to the photocentre of the two components and α represents the semi-axis major of the photocentric orbit:

$$\alpha = (\mathrm{B} - \beta)a \tag{6.16}$$

where

$$\beta = \frac{l_2}{l_1 + l_2} = \frac{1}{1 + 10^{0.4\Delta m}}. \tag{6.17}$$

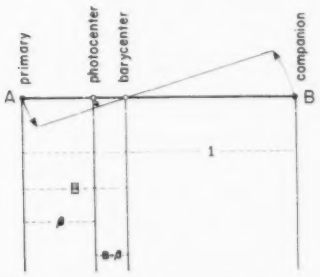

FIG. 6.5—Relative spacings between components, barycentre and photocentre for photographically unresolved binaries.

Here l_1 and l_2 are the luminosities of the components, Δm the difference in magnitude, companion *minus* primary.

From a set of observations covering a sufficient portion of the orbit, α may be determined.

The mass-ratio of the two components is now obtained from the relation

$$\mathrm{B} = \frac{\alpha}{a} + \beta \tag{6.18}$$

and the separate masses may be derived.

5. General analysis of photocentre. Unseen companions

A perturbation, indicating an unseen companion object may be analyzed in the following way. The general formulae for orbital analysis of a measured photocentre are

$$\begin{aligned} \Delta x &= (B)x + (G)y \\ \Delta y &= (A)x + (F)y. \end{aligned} \tag{6.19}$$

The geometric elements (B) (A) (G) (F) are related to the orientation factors and the Thiele-Innes constants as follows

$$\begin{aligned} (B) &= -\frac{\alpha}{a} B = \alpha(b) = \alpha(-\cos w \sin \Omega - \sin w \cos \Omega \cos i), \\ (A) &= -\frac{\alpha}{a} A = \alpha(a) = \alpha(-\cos w \cos \Omega + \sin w \sin \Omega \cos i), \\ (G) &= -\frac{\alpha}{a} G = \alpha(g) = \alpha(+\sin w \sin \Omega - \cos w \cos \Omega \cos i), \\ (F) &= -\frac{\alpha}{a} F = \alpha(f) = \alpha(+\sin w \cos \Omega + \cos w \sin \Omega \cos i). \end{aligned} \tag{6.20}$$

The formulae for a measured position as a background of faint stars are now

$$\begin{aligned} X &= c_x + \mu_x t + \pi P_\alpha + (B)x + (G)y \\ Y &= c_y + \mu_y t + \pi P_\delta + (A)x + (F)y. \end{aligned} \tag{6.21}$$

The orbital analysis for determining the dynamical elements P, e and T and the geometric elements (B), (A), (G) and (F) has been described elsewhere. The geometric elements may be converted into the scale α and the orientation constants Ω, ω and i.

The semi-axis major α and period P of a photocentric orbit yield the mass-function

$$\frac{\alpha^3}{P^2} = (\mathrm{B} - \beta)^3(\mathfrak{M}_A + \mathfrak{M}_B) \tag{6.22}$$

which also may be written as

$$\mathfrak{M}_B - \beta(\mathfrak{M}_A + \mathfrak{M}_B) = \alpha P^{-2/3}(\mathfrak{M}_A + \mathfrak{M}_B)^{2/3}. \tag{6.23}$$

For an adopted value of the combined mass, a lower limit of the mass of the companion may, therefore, be obtained.

A small photocentric orbit, discovered as a perturbation, implies a small value of $(\mathrm{B} - \beta)$, but not necessarily a small value of B. Interpreting a small perturbation as caused by a planetary companion is

never justified unless outside evidence indicating a negligible luminosity of the unseen companion is available.

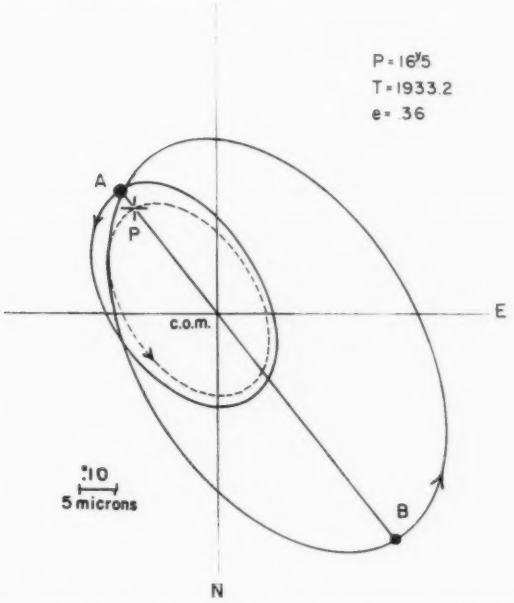

FIG. 6.6—The orbits of the components and the photocentre (dashed ellipse) for the astrometric binary Ross 614. The positions A, B, and P are shown for the date of the visual discovery of the companion.

For further information—consult the following articles by the author:

1. "Long-Focus Photographic Astrometry", a survey with particular emphasis on resolved and unresolved astrometric binaries. *Popular Astronomy*, vol. 59, pp. 65–79, 129–137, 176–191, 243–254, 1951. Also *Contr. Inst. d'Astrophysique*, Sér. A, Nr. 81, 1951. *Sproul Observatory Reprint* No. 73.

2. "Planetary companions of stars", *Vistas in Astronomy*, vol. 2, pp. 1040–1048, 1956. *Sproul Observatory Reprint* No. 97.

3. "Visual binaries", *Encyclopedia of Physics*, vol. 50, 187–224, 1958. *Sproul Observatory Reprint* No. 104.

(*Concluded*)

A CANADIAN-BUILT BIREFRINGENT MONOCHROMATOR

By W. A. Knox
Calgary Centre

Introduction. The privately built Vista del Cielo Observatory is primarily devoted to solar work, although a limited amount of night-time observing is done for special projects.

The observatory building, forming an annex to the garage (see figure 1),

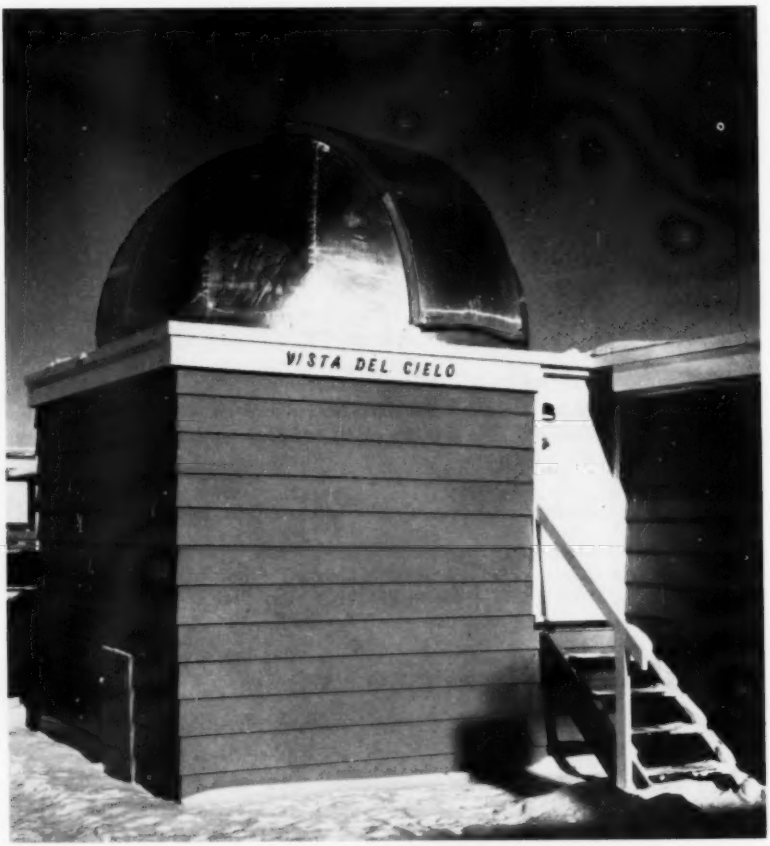

Fig. 1—Exterior of the observatory.

supports a ten-foot aluminum-clad dome. The dome rotates on four large castors which are bolted to the supporting walls. The base ring of the dome is a three-inch I-beam bent to the required radius. The ring serves as an inverted track and as a foundation for the curved ribs which were cut from $1\frac{1}{8}$-inch plywood panels. The shutter is split, with the top half rolling over the back of the dome and the lower half opening downwards on hinges.

Three telescopes are in use: A 10-inch reflector for night-time observing, a 5-inch refractor used mainly for sun-spot projection, and a 3-inch coronagraph or heliograph for prominence study. An M-17 elbow telescope serves as a finder. (See figure 2.)

The instrument cluster is mounted on a clock-driven equatorial mounting which, in turn, is bolted to a large concrete pier. Push-button controlled slow motions are provided for both axes.

The observatory building, all of the mechanical work, including the clock, and a part of the optical work was done by the author.

The Coronagraph and its Purpose. Since the other two telescopes are rather conventional, they will not be described further; we will confine the remainder of our discussion to the coronagraph, its use and construction.

The coronagraph is a specialized telescope designed to see prominences on the sun. Normally, due to the glare of the solar disk and to the light-scattering of the earth's atmosphere, prominences are invisible to the casual observer except during a total eclipse. The coronagraph renders the prominences visible by first, blocking off the bright face of the sun with an occulting disk to form an artificial eclipse. Next, the edge of the sun and the accompanying prominences are examined through a special filter tuned to the exact frequency of the hydrogen alpha spectral line. The filter, or monochromator, removes the background glare due to light scattering by the earth's atmosphere for all frequencies except the red of hydrogen light.

Figure 3 shows some pictures of various types of prominences, taken through the Vista del Cielo coronagraph.

Theory of the Monochromator. The heart of the coronagraph is the filter, or, more correctly, the quartz birefringent polarizing monochromator. Most monochromators will have a passband ranging from one-half to five angstrom units wide. They can be tuned over a restricted range of wave-lengths by accurate temperature control.

The theory of operation is as follows:

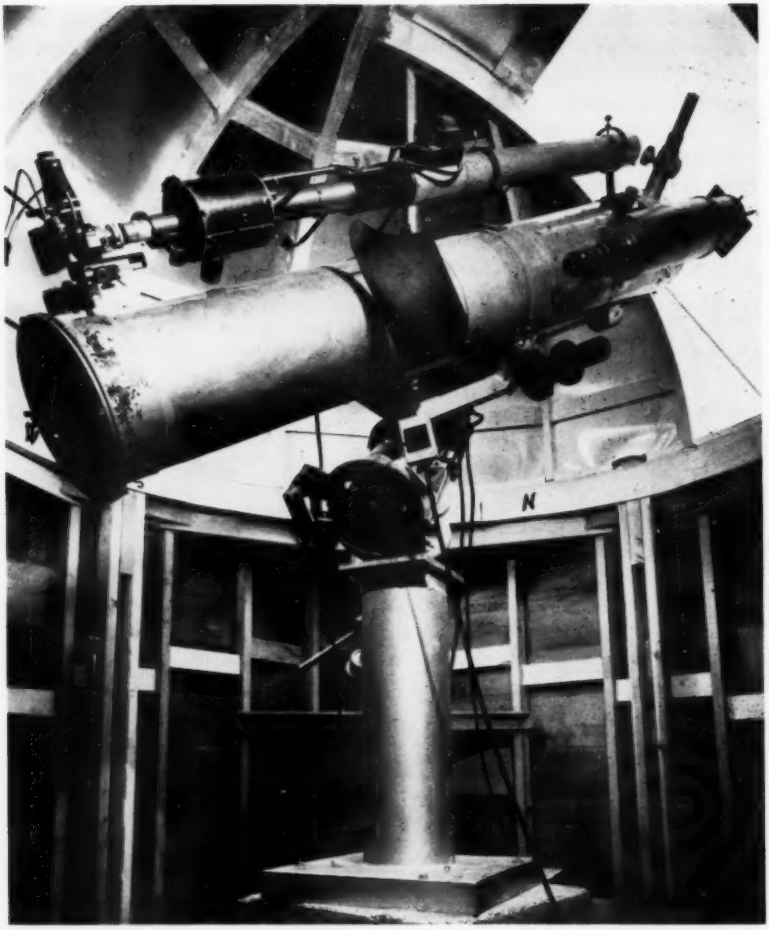

FIG. 2—Interior of the observatory showing the main tube of the 10-in. reflector. The short stubby telescope on the side is the 5-in. sun-spot projector. The coronagraph is the long thin telescope on top of the main tube.

Let a slab of birefringent material such as crystaline quartz, be cut with its light-transmitting faces parallel to the principal axis of the quartz. The quartz plate is placed between parallel polarizers whose axis is rotated 45° to the crystal axis. If white light is beamed through

the polaroid-quartz sandwich and examined through a spectroscope, the spectrum will be seen to be crossed by a series of evenly spaced bright and dark bands. The width and separation of the bands will depend upon the thickness of the crystal plate. Let a second plate, exactly half the thickness of the previous one, be placed in front of the original plate. This second plate will have dark bands spaced at exactly twice the interval of the first. The dark bands of the second plate will block out every alternate bright band of the first plate. The resultant spectrum of the two plates will be a series of bright bands with twice the separation of those due to a single plate. If six or seven plates are stacked in series, all of the spectrum will be blocked out except for three or four isolated bright bands. All except one selected band can be blocked off by means of a suitable glass prefilter. If a commercial multilayer interference filter is available, at least one quartz plate can be eliminated. The width of the final passband is controlled by the thickness of the longest quartz

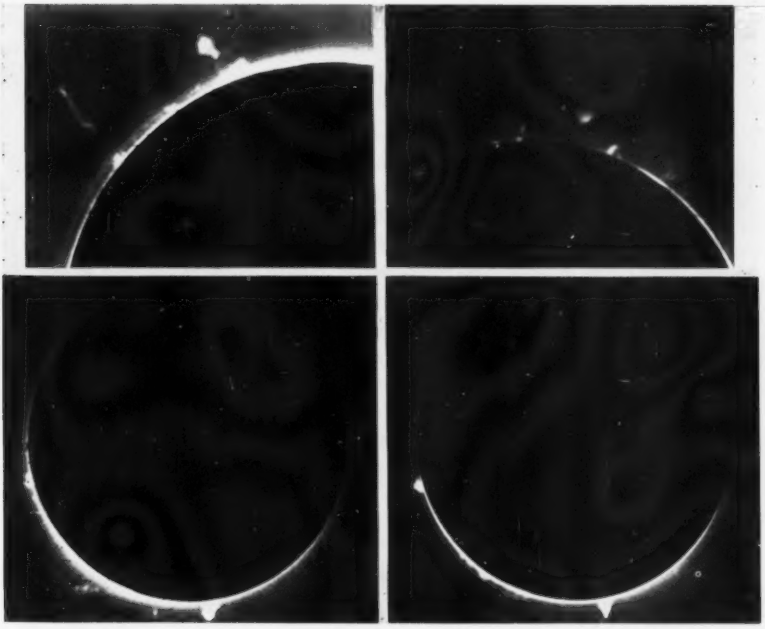

FIG. 3—Photographs taken with the coronagraph. *Upper left*: 1960 Feb. 13; *upper right*: coronal condensations; *lower left*: 1960 June 18; *lower right*: same prominence group on 1960 June 19.

element. The separation between unwanted bands is governed by the dimensions of the thinnest crystal.

Because of the physical limitations of the size of available optical quartz, the longest plate usually will be around two inches, yielding a final passband of about four angstroms for the completed filter. Filters with narrower passbands have been constructed, using calcite for the thickest elements. The passband must be less than 10 angstroms before prominences become visible.

Since the dimensions of the quartz plates determine the width and wave-length of the passband, the entire monochromator must be kept at a temperature constant within 1/2° F. To minimize light loss by internal reflection at the various quartz-polaroid interfaces, the elements are immersed in an oil bath.

Tools and Materials of Construction. A professionally-manufactured monochromator of 1- to 1 1/2-inch aperture costs about as much as a medium-priced car. For rather obvious reasons the one described here was a do-it-yourself project. The construction of a monochromator requires considerable time and patience but the technical difficulties are not beyond the capabilities of the amateur who has made a couple of mirrors or lenses. All of the equipment and supplies can be obtained locally by the Canadian amateur except, perhaps, the optical quartz and optical mica.

A modestly-equipped shop including a 10-inch lathe or larger, equipped with a milling attachment, is rather necessary. At least one good micrometer reading to 0.0001 inch is required. Final checking of the thickness of a quartz plate is done optically using a spectroscope of good resolving power. If one is not available on a loan basis, it will have to be made for the occasion. A prism spectroscope is preferable to a grating.

A motor-driven diamond saw and polishing lap are desirable but not essential. This machine can be made easily, using spindles and bearings available from dealers in home machine shop components. An iron foundry can cast the laps. The diamond saw can be bought from suppliers of geological and mining laboratory equipment. Any spectacle manufacturer will supply carborundum grits and cerium oxide at a few cents per handful.

The only really difficult item to obtain is the quartz. A single crystal of optical quartz large enough to make a seven-element filter of 1 inch aperture would cost fifty to seventy-five dollars. The best place to get quartz is probably Ward's Natural Science Establishment, Rochester, N.Y. (if you are lucky).

Testing the final thickness of each plate requires the use of a hydrogen discharge tube as the standard of measurement. A suitable discharge tube having high intensity and long life, can be made by any neon sign company for the price of a contribution to the coffee fund. A mercury vapour discharge tube for testing flatness of the plates can be obtained similarly. A small 2000-volt neon sign transformer will activate the discharge tubes.

The auxiliary optical components can be obtained from one of the many scientific salvage companies.

Excellent detailed instructions for building a monochromator will be found in references 1 and 3.

Description and Use of the Coronagraph. The optical train of the Vista del Cielo coronagraph consists of a 3 1/16-inch objective, the occulting disk, a field lens, a collimator lens, the filter in its constant temperature cell, a re-imaging lens, and the eyepiece or camera. The filter consists of seven quartz plates, a mica shim, and eight polaroids. It has an aperture of 1 inch and operates at a thermostatically controlled temperature of 79° F. Heat is provided by two, 50-watt, wire wound resistors. The optical arrangement used, is one of three or four alternate designs, which are illustrated in detail in any one of the first five references.

A Leica 35-mm. camera with a micro-mirror reflex housing is used for photography. The reflex feature is essential for accurate focusing. The Leica reflex housing has a clear glass focusing screen and a magnifier, equivalent to a wide-field eyepiece. Ordinarily no other eyepiece is necessary for visual work. Thus, the camera assembly always remains in the optical train as an integral part of the telescope. The use of the reflex housing as an eyepiece offers the additional advantage that it can be fitted with a special lens to correct for the defects of the user's eye, obviating the need for glasses when observing.

Since the image of the sun at the prime focus of the coronagraph is rather small, various image-amplifier arrangements are employed using eyepiece projection alone or in combination with the camera lens, or camera lens alone with or without extension tubes. It is possible to photograph the entire sun on one 35-mm. frame or to enlarge the image to such an extent that a single prominence occupies most of the picture.

Super Anscochrome, daylight type film produces excellent colour slides of prominences, although the graininess and colour rendition varies from roll to roll. Overexposure of this film will contribute to severe background scatter, large grain and poor colour fidelity. Although many have been tried, the only black and white film that seems to work with

reasonable speed is Eastman 103 E or F. This film should be processed using D 76 developer along with a hardener at temperatures on the cool side of 68° F., otherwise the emulsion becomes too soft and delicate. Exposure time for both Anscochrome and Eastman 103 F is 1/10 to 1/4 second for moderately bright prominences. Faint coronal clouds may require an exposure of 1 second to register on the film satisfactorily.

The best time for observing the sun is from early morning to just before noon. After this time, in Calgary at least, air turbulence sets in or clouds develop. Thin haze due to high cirrus clouds or due to ice crystals on very cold days in winter, causes a severe background scatter that completely hides all but the brightest prominences.

There is usually a certain amount of prominence activity on most days regardless of the presence or absence of sun-spots. Occasionally, fairly spectacular eruptions are seen. Probably the most fascinating pastime in astronomy is to watch a large prominence develop to a height of many tens of thousands of miles above the sun's surface in the short space of half an hour. On rare days of perfect seeing, the tiny spicules at the edge of the chromosphere can be observed, but due partly to the poor seeing conditions at Calgary and partly because of the small aperture of the coronagraph objective, this fine detail is almost impossible to photograph.

In conclusion I might add that the satisfaction derived from prominence observing is well worth the time and effort it took to construct the instrument.

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NOTES FROM OBSERVATORIES

DOMINION OBSERVATORY, OTTAWA, ONTARIO

Positional Astronomy: The first pictures taken with the Mirror Transit telescope (manually operated) recorded to the 11th magnitude with a 30 second exposure, an extension of about 2 magnitudes beyond our Meridian Circle telescope; normal exposure time is 40 seconds. Controlled drive to the eye end and much wiring have still to be completed before observing commences. The P.Z.T. was inoperative from May 9–25 when it was moved to its new location, about 300 feet south-east of the main building. An improvement is indicated by a reduction in the mean error of latitude for the night from $\pm 0''.08$ to $\pm 0''.05$. The three C.H.U. transmitters (3330 kc, 7335 kc and 14670 kc) have been equipped with a new speaking clock. A new Western Electric oscillator located at the transmitter site generates both the carrier frequencies and the signal pips.

Stellar Physics: The official opening of the Dominion Radio Astrophysical Observatory near Penticton took place on June 20. Further testing of the 84-foot telescope has continued. The mirrors of the horizontal solar telescope in Ottawa have been re-aluminized and the solar magnetograph is in an advanced stage of construction. The Perseid meteor shower was well observed at the meteor observatories in Alberta although bright moonlight limited some parts of the programme.

Geomagnetism: The three-component airborne magnetometer made survey flights between July 11 and August 30. A total of 42,000 line-miles was flown between northern Greenland and Bermuda and between Ottawa and Europe. The magnetometer was on display during the I.U.G.G. meetings in Helsinki. A chart depicting lines of equal magnetic declination and annual change for the epoch 1960.0 was published in June.

Gravity: As part of a long-term project to publish regional Bouguer anomaly maps the field programme was accelerated during the past summer by the use of helicopters in two areas. In northern Saskatchewan some 1850 stations at 8 mile intervals covering an area of some 100,000 square miles were observed. Two staff members attached to the Polar Continental Shelf Project observed at some 400 stations on the Arctic Islands, Ellef Ringnes, Amund Ringnes, Meighen, Lougheed, and on

the intervening sea ice. These observations were for regional mapping, and additional readings were taken over two gypsum domes on Ellef Ringnes Island and over the Meighen Island Glacier. Three 1:500,000 Bouguer anomaly maps of northern Quebec, compiled in the new map compilation section of the division, are ready for reproduction and should be available for distribution in the spring of 1961.

Seismology: During the period covered by this report field studies were made in British Columbia and in the vicinity of Ottawa. The Ottawa studies were designed to test tape recording equipment developed here.

Personnel: Recent visitors have included Dr. A. F. Cook of Harvard College Observatory, Dr. and Mrs. R. M. Petrie and Dr. A. B. Underhill of the Dominion Astrophysical Observatory, and Dr. J. L. Locke now at Penticton. Distinguished visiting scientists temporarily on the staff are Dr. R. Ananthakrishnan of the Kodaikanal Observatory, India, and Dr. H. Honda from the University of Tokyo. Dr. K. Kasahara from the Earthquake Research Institute, University of Tokyo, is a Postdoctorate Fellow. Staff members have attended the following meetings where a number of papers were presented: The Royal Society of Canada in Kingston—Drs. C. S. Beals, I. Halliday, M. J. S. Innes and J. A. Rottenberg. The National Committees for Canada of the I.A.U. and U.R.S.I., in Penticton, and the official opening of the Dominion Radio Astrophysical Observatory—Dr. C. S. Beals, Miss M. S. Burland, R. W. Tanner and M. M. Thomson. The I.U.G.G. in Helsinki, Finland—Drs. J. H. Hodgson, E. R. Niblett, P. L. Serson and P. L. Willmore and A. C. Hamilton and W. G. Milne. The A.A.S. in Mexico City—G. A. Brealey. The U.R.S.I. meetings in London, England—Dr. J. L. Locke. R. W. Tanner visited Queen's University to assist in the orientation of their new 15-inch reflector. New staff appointments include G. Atkinson, D. R. Auld, Mrs. D. Cleary, E. A. Garland, M. Glab-Akbowicz, A. K. Goodacre, Dr. F. Kollar, Miss M. Metzger, J. O'Brien, E. W. Orge, A. Overton, Miss C. L. Sievenpiper, J. R. Stewart, M. Strader and Dr. H. Weber. Those who have recently left the staff are W. E. Ross who retired after many years service as Officer-in-Charge of Agincourt Observatory; Miss C. Sayn-Wittgenstein who resigned from the Geomagnetic division to get married; Dr. P. L. Willmore who returned to England to set up a network for the study of earthquake seismology, he expects to be stationed eventually in Cambridge. G. Carr was recently transferred from Meanook Magnetic Observatory to the Geomagnetic Laboratory here.

MIRIAM S. BURLAND

VARIABLE STAR NOTES

By Margaret W. Mayall

The American Association of Variable Star Observers, Cambridge, Mass.

061115 *CZ Orionis.* CZ Orionis is one of the most interesting of the U Geminorum-type variables, but due to its faintness, it is not as well observed as it deserves to be. The star is listed in the *General Catalogue of Variable Stars* (1958 edition) as varying from 11.8 to 16.2 photographic magnitude, with a mean cycle of 30 days. The colour index is small, so the visual range is about the same as the photographic.

Any observer who can observe down to about the 13th magnitude should find this an interesting star to add to his programme. If it can be seen brighter than 13, it is almost certainly near a maximum.

The variability of CZ Orionis was discovered by Dr. C. Hoffmeister of Sonneberg, Germany, in 1928. Maxima were observed and published by Hoffmeister, Nijland, Jacchia, Gerasimovic, Koyama, and Rosino, in addition to the Japanese and American variable star associations. In recent years, the variable star section of the Royal Astronomical Society of New Zealand has added it to their observing programme.

Table I lists the maxima observed by the A.A.V.S.O. from 1937 to 1960. Successive columns give the Julian Day (omitting the first three figures) of the observed maxima; the weight on a scale of 5 (1, very doubtful; 5, quite certain); the observed magnitude and its weight; and finally the approximate width of the curve at one and one half magnitudes below average maximum brightness.

The shape of the light curve varies radically between the maxima. Some are very sharp, and the star increases about 4 magnitudes and then decreases the same amount—all in about 3 to 5 days. At other times, the cycle seems to take about 10 or more days.

An example of the rapid type of curve is the maximum at J.D. 34798. On 793, it was observed by Cragg at 15.8; on 796, Peltier called it fainter than 13.3; on 798, Carpenter said 11.9; and on 804 Peltier found it again fainter than 12.9. Further confirmation of the rapid drop came from the New Zealand observers, when Jones observed it at 12.8 on 800, and 13.1 on 801.

The maximum just preceding this rapid one was a very wide one. The greatest brightness occurred on 34766. For two days, 765 to 767, it was brighter than 12. It dropped to 12.3 on 769 and then increased again to brighter than 12 from 770 to 772. On 774 it was down to 12.9, and on 776, Carpenter observed it at 14.6.

Several instances occur where it is difficult to tell whether there are two distinct maxima or whether it is one very long irregular type.

Observers are needed who have large telescopes, and who can follow CZ Orionis nightly over a period of time.

Figure 1 shows the frequency of intervals between the observed maxima. It indicates that the mean interval is slightly less than the 30 days listed in the catalogue, and is perhaps nearer 27 days. The intervals longer than 40 days are probably double intervals, with an unobserved maximum in between the observed ones.

TABLE 1

061115 CZ ORIONIS, MAXIMA 1937–1960

J.D.	Wt.	Mag.	Wt.	Width (13.5)	J.D.	Wt.	Mag.	Wt.	Width (13.5)	J.D.	Wt.	Mag.	Wt.	Width (13.5)
8870	3	12.1	3	7–?	2624	2	12.6	2	?	4831	4	11.8	4	5
8902	4	12.2	3	3–4	2646	3	12.8	1	7–9	4992	2	11.9	3	?
8962	4	12.7	2	8–?	2674	1	12.5	1	?	5015	2	12.8	1	3–?
8989	1	12.9	2	3–?	2832	1	11.4	1	?	5064	2	13.0	1	?
9189	2	12.5	2	4–?	2854	2	12.0	1	?	5082	2	12.4	2	?
9216	3	12.3	3	9–?	2890	3	12.2	2	?–9	5097	3	12.5	2	8
9243	2	13.0	2	3–7	2923	2	11.6	3	?	5152	4	11.3	4	11
9286	4	12.6	3	5–8	2993	5	11.7	5	10–?	5181	4	12.0	3	3
9316	5	12.0	5	10–17	3275	4	12.9	2	?–7	5214	2	12.4	2	?
9340	5	12.5	4	4–6	3294	3	12.2	2	?–10	5424	5	11.6	5	4–?
9358	2	—	—	5–8	3321	3	12.2	2	4–?	5452	4	12.2	3	3
9396	4	12.7	3	7–?	3350	2	?	—	?–7	5481	4	12.4	3	4
9495	3	13.0	2	4–?	3380	4	12.1	4	4–10	5502	2	11.8	2	?
9522	4	11.8	5	10–?	3533	2	12.5	2	3–?	5519	3	12.0	3	?
9547	3	12.9	2	3–?	3569	4	11.8	4	10–?	5549	4	11.8	4	13
9571	2	12.6	2	6–?	3623	4	12.2	3	6	5602	2	12.4	2	?
9637	4	12.6	2	3–4	3646	2	12.8	2	6–?	5761	4	12.1	4	4–?
9687	2	12.2	3	4–?	3659	3	12.4	2	13–?	5802	3	12.4	3	5
9719	2	11.9	2	?	3680	3	12.2	2	3	5822	1	12.5	1	?
0020	4	12.1	4	4–?	3701	5	12.4	4	5	5857	2	12.7	2	4–?
0122	3	12.0	2	?–14	3725	3	12.1	3	16	5886	5	11.8	5	3
0293	1	12.8	1	?	3782	1	11.6	1	?	5929	4	11.2	4	8–?
0403	2	13.0	2	4	3923	3	11.9	3	?	6026	1	11.9	1	?
0429	2	11.6	3	?–10	4005	3	12.2	3	3–5	6086	1	12.3	1	?
0692	3	12.0	3	11–?	4020	4	11.8	4	10–?	6116	5	12.2	4	3
0775	2	11.8	3	?	4047	4	12.5	3	4–6	6140	2	12.3	2	?
0810	2	12.1	3	4	4073	4	12.0	4	3	6190	2	12.5	2	4
0853	3	11.8	4	5–?	4100	5	11.8	5	?	6226	4	11.8	4	5–?
1122	4	12.4	4	12	4125	4	12.3	3	5	6252	3	12.3	3	?–8
1434	2	12.4	2	?	4131	1	12.4	1	?	6269	2	12.4	2	3–?
1472	3	12.2	3	5–?	4269	2	12.2	2	3–?	6286	2	12.8	2	?
1544	2	12.2	2	?–13	4308	5	12.1	4	8	6301	2	12.5	2	?–5
1747	2	11.8	2	6–?	4331	3	12.0	3	6–?	6312	2	12.6	2	?
1843	5	11.7	5	10–?	4365	3	12.1	3	3–?	6498	3	12.1	3	4–?
1875	3	12.0	3	?	4390	3	12.0	3	3–?	6521	1	12.3	1	?
1935	5	12.0	5	10	4409	3	12.3	3	5–?	6528	2	12.0	2	?
2152	4	12.2	4	?	4439	3	11.8	3	8–?	6587	4	11.8	4	5–?
2182	3	12.8	1	5–?	4470	4	11.8	4	3–?	6606	4	12.2	4	3–?
2203	3	12.5	1	5–?	4500	3	12.0	3	?	6633	3	12.0	4	12
2240	3	11.9	3	7–12	4632	4	12.4	4	6–?	6658	2	11.0	2	?
2286	3	12.2	1	3	4666	3	12.0	3	8–?	6666	3	12.1	3	4–?
2423	2	12.0	2	?	4691	1	12.7	1	?–10	6805	1	11.9	1	?
2454	3	12.3	2	3	4707	3	12.1	3	2–?	6870	1	12.8	1	?
2500	3	12.0	3	7–?	4739	3	12.6	2	3–5	6903	2	11.7	4	8
2562	5	12.2	5	6	4766	3	11.6	3	10–?	6939	2	12.2	2	3–?
2588	2	12.7	2	?	4798	4	11.9	4	4	6986	2	11.8	4	10–?

Observations received during July and August 1960: A total of 12,178 was received: 4,439 from 97 observers in July, and 7,739 from 112 observers in August.

Observer	July		August		Observer	July		August	
	Var.	Ests.	Var.	Ests.		Var.	Ests.	Var.	Ests.
Adams, R. M.	84	151	91	191	Gonthier, A.	...	...	15	36
Anderson, Carl	5	15	7	48	Grossenbacher, R. W.	...	...	12	12
Anderson, Curtis	242	338	216	363	Guerrero, J. S.	...	...	7	17
Anderson, Edward	8	15	4	4	Halbach, E. A.	...	...	8	8
Anderson, Roy	2	2	...	...	Hartmann, F.	95	112	120	131
Axelson, K.	1	3	5	10	Hicks, R. L.	...	...	10	48
Ayala R., H.	5	21	15	48	Hiett, L.	6	11	6	11
Balassa, T.	...	...	9	78	Hudson, J. A.	...	...	10	10
Ball, A. R.	16	30	13	44	Hull, A.	2	2	...	...
Barrera, S.	...	...	9	21	Humphrey, D. R.	...	...	20	46
Barroso, J. J.	11	46	14	46	Hunter, T.	1	1	2	2
Bash, D.	8	8	10	14	Hurless, C.	...	...	12	61
*Berg, J.	38	66	21	58	Hutchings, N. O.	...	...	9	11
Bicknell, R. H.	...	...	14	52	Ibanes, A.	...	...	2	2
Blunck, V. H.	7	25	...	...	James, R. A.	...	...	9	11
Borquez, P.	...	...	9	126	Judd, D.	18	18	...	...
Braune, W.	28	85	...	...	Kaminski, W. J.	11	13	16	16
Breckinridge, J.	2	2	1	1	Kammel, J.	1	1	1	2
Buckstaff, R. N.	22	56	29	171	Kelly, F. J.	15	21	12	18
Burden, J.	1	1	...	...	Kindt, O. H.	...	...	15	16
Burt, S. E.	...	...	5	13	Knowles, E.	...	...	4	4
Byrd, J.	3	3	...	...	Knowles, J. H.	15	20	33	94
Byrd, W.	3	3	3	3	Lacchini, G. B.	36	159	35	229
Campillo, F.	...	...	4	4	Lagos, O.	...	...	2	2
Carbacho, P.	...	...	2	40	Lattey, M.	9	9	12	23
Carlisle, J. H.	2	3	...	...	Lewindon, F.	...	...	2	6
Carpenter, C. H.	18	18	...	...	Lovi, G.	5	5	...	...
Celis S., L.	...	...	10	110	Lowder, W. M.	10	18	...	...
Conklin, J. H.	3	3	...	...	Lucas, D.	...	...	5	7
Cragg, T. A.	255	271	316	334	Lynch, J. S.	2	2	7	7
Debono, I. P.	...	...	7	7	Mahoney, D.	1	1	...	...
de Kock, R. P.	...	...	151	402	Martin, K.	1	1	...	...
de la Riva, J. A.	...	...	11	76	Martinez G., A.	...	...	6	174
de la Vega, R.	...	...	50	888	Matthies, D.	1	1	6	6
de la Vega, X.	...	...	1	1	McFarland, T.	15	19	30	112
Diedrich, Del.	3	6	2	4	McPherson, C. A.	46	61	36	36
Diedrich, G.	9	15	3	8	Meisel, D. D.	...	...	1	1
Douglas, J.	1	1	2	2	Miller, R. W.	...	...	9	9
Dueck, A.	...	...	5	5	Miller, W. A.	19	26	28	33
Eckman, M.	3	3	...	...	Molina, W.	...	...	7	7
Ellerbe, J. E.	5	8	...	...	Montague, A. C.	28	43	13	16
Engelkemeir, D.	9	14	9	36	Morgan, F. P.	6	11	6	6
Evans, P.	18	137	...	...	Mourao, R. deF.	5	5	5	5
Farmer, R.	3	5	6	10	Mourilhe S., P.	14	37	20	57
Fernald, C. F.	168	414	176	313	Muniz B., L.	14	42	20	64
Fletcher, D. M.	9	11	...	...	Newton, Mrs. J.	...	...	3	3
Ford, C. B.	94	101	...	...	Nightingale, H. C.	...	...	9	29
Frogel, J. A.	2	2	3	4	Oberstatter, A.	...	...	6	19
Fuller, K.	65	65	34	36	Olmstead, M.	3	4	...	...
Garland, G.	...	...	2	2	Oravec, E. G.	140	215	137	281
Giffen, C. H.	27	69	21	1007	Orchiston, D. W.	...	...	54	230
Glenn, F. R.	1	10	...	...	Overbeek, M. D.	89	523	...	...
Glenn, W. H.	1	11	...	...	Pearcy, R. E.	5	5	2	2
Godfrey, N. B.	38	38	...	...	Pearlmutter, A. E.	7	7	...	...

* Plus 25m AE Aqr.

Observer	July		August		Observer	July		August	
	Var.	Ests.	Var.	Ests.		Var.	Ests.	Var.	Ests.
Peltier, L. C.	18	64	25	138	Stowe, D.	1	1	...	...
Price, F. J.	19	31	...	...	Szekely, C.	...	...	2	7
Price, R. T.	...	...	33	71	Taboada, D.	36	102	...	...
Quester, W.	6	19	...	...	Takeuchi, T.	...	...	2	4
Renner, C. J.	98	98	187	187	Tavares, O. C.	8	12	16	37
Rettig, P.	...	...	5	8	Teran, M.	...	...	3	3
Riquelme, D.	...	...	3	3	Thaly, K.	...	...	8	55
Rizzo, P. V.	10	20	17	28	Thomas, M. A.	2	13	...	...
Robinson, L. J.	97	157	64	99	Traynor, F.	...	...	16	35
Rosebrugh, D. W.	11	102	12	141	Tsai, C. H.	61	92	30	51
Schiff, S.	7	9	8	10	Ungar, S.	1	1	...	...
Schilling, M.	...	...	5	5	Valdez, M.	5	9	...	...
Sealy, R. N.	4	8	...	...	van Zyl, L. L.	24	79	30	64
Segers, C. L.	...	...	20	47	Walsh, J.	6	6	10	10
Seldon, P.	12	12	...	...	Wend, R. E.	2	2	...	...
Severin, M. A.	7	19	7	10	Wilford, F.	1	1	...	...
Sharpless, A. P.	...	...	17	17	Williams, I.	1	1	...	...
Shinkfield, R. C.	...	...	18	46	Williamson, L. J.	...	...	7	28
Skhal, R. G.	...	...	1	1	Williamson, P. L.	...	...	9	38
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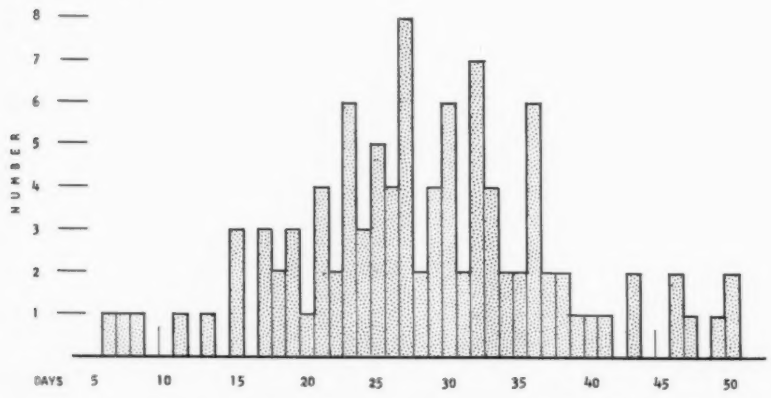

Frequency of intervals between observed maxima of CZ Orionis.

NOTES

The Walter Helm Endowment Fund

Mr. Walter J. Helm of Port Hope, Ontario, who passed away on June 5, 1960, was a long-time member of our Toronto Centre. He had been Vice-President and General Manager of The Midland Loan & Savings Company in Port Hope prior to its being taken over by The Canada Permanent Mortgage Corporation, at which time he became Manager of their Port Hope branch. He was retired at the time of his death.

Mr. Helm has left substantial capital bequests to the Royal Astronomical Society of Canada under the terms of his Will. It will probably be many years before the capital bequests become operative in so far as the Society is concerned, since interest from the capital will go to certain of his descendants for their respective life times. Upon their deaths certain amounts of capital will be freed until eventually a large sum will have been paid and transferred to The Royal Astronomical Society of Canada in order to create a fund to be known as The Walter Helm Endowment Fund. At today's values, this sum approximates $400,000 according to The Canada Permanent Trust Company, an Executor and Trustee.

The clear annual income from The Walter Helm Endowment Fund shall be used "by the said Society for the general purposes of the David Dunlap Observatory located in the vicinity of Richmond Hill, Ontario, and in the event of the destruction of the said Observatory at any time then unless and until the said Observatory has been rebuilt the said income shall be used by the said Society for research in the Science of Astronomy".

Mr. Helm has similarly arranged for a $100,000 Walter Helm Scholarship Fund at the University of Toronto for scholarships, bursaries and fellowships for the study of astronomy.

It is with regret that we learned of Mr. Helm's death. However, he has done a remarkable and wonderful thing by creating these Funds. By so doing, he will be making a continuing contribution to further Canadian astronomy. A Resolution was passed by the National Council of The Royal Astronomical Society of Canada at a meeting on October 3, 1960, expressing deep gratitude for these valuable bequests.

W. R. Hossack, *National Treasurer.*

REVIEW OF PUBLICATIONS

A Beginner's Guide to the Skies by R. Newton Mayall and Margaret W. Mayall. Pages 184; 4½×7½ in. New York, G. P. Putnam's Sons, 1960. Price $2.50.

This is still another book for observers produced by the talented husband and wife team of R. Newton and Margaret W. Mayall (see also this JOURNAL, vol. 49, p. 135; vol. 54, p. 90). As the title indicates, this little volume is intended to help the beginner become acquainted with the night sky, and technical details are kept to a minimum. However, fundamental information is included in the first third of the book. Simple star charts, giving details of the constellations visible from northern latitudes constitute the rest of the book. *A Beginner's Guide to the Skies* forms an excellent introduction to the heavens. Then the observer can graduate to the more comprehensive book *Field Book of the Skies* by William T. Olcott and revised and edited by the Mayalls.

RUTH J. NORTHCOTT

The Monthly Evening Sky Map, vol. 54, no. 506, July–August 1960. Pages 22; 8½×11 in. St. Louis, Sky Map Publications, Inc. Annual subscription (6 parts) $3.00.

The Monthly Evening Sky Map is a long-established publication, having been founded in 1905 by Leon Barritt. About a year ago the *Sky Map* was bought from its previous owners, and has experienced a change in format to become an attractive, well-illustrated little magazine. The editor and publisher is Donald D. Zahner; the associate editor is Armand Spitz.

This issue contains the evening sky maps for July and August, an equatorial sky map showing the positions of the sun and planets during this period, and tables of phenomena. There are short articles covering such topics as the Milky Way, summer meteor showers, and Jupiter; a book review section is included.

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